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ADS-B UAT MOPS

Meeting #11

Issues Related to the Potential Use of a Suppression Bus for UAT

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SUMMARY

This paper addresses the issue of how UAT should use a suppression bus if one is available on a particular aircraft. Tom Mosher of UPS AT has raised this issue in some correspondence that occurred between meetings 10 and 11 of WG5. **WG5 is requested to consider if this paper should be converted into a MOPS appendix.**

This paper deals with the determination of the most effective way to use a suppression bus (if one is available) to control the operation of UAT. The bus becomes active whenever any of the L-band transmitters on board an aircraft is transmitting. The bus can be used to blank the UAT receiver function to prevent the occurrence of ringing (or pulse-stretching) phenomena. It might also be used to suppress the transmission of a potential ADS-B message. It might be necessary to implement this second kind of suppression if the intermodulation products (IMPs) caused by simultaneous transmission generate intolerable interference to some other receiver. On the other hand, transmission suppression might have a negative impact on ADS-B performance if it occurs with a high enough probability. This paper will present a brief investigation of this issue.

The cosite interference environment that will be used in this analysis is provided in working paper UAT-WP-10-4, by Mike Biggs (a draft of Appendix G). Currently, all capability classes are assumed to suffer the same interference, which is summarized by Table 1.

Table 1: Assumed Cosite Interference Environment

Event Type	Frequency (MHz)	Event Interval (μsec)	Events per Second
DME Interrogations	1025-1150	19	70
ATCRBS Replies	1090	20	200
Mode S Interrogations	1090	64	4.5
Mode S Interrogations	1030	20	5
Whisper Shout Interrogations	1030	25	80

The frequencies of the potential IMPs can be predicted using the following formulas:

$$F_+(n) = F_2 + (n-1)(F_2 - F_1)/2$$
$$F_-(n) = F_1 - (n-1)(F_2 - F_1)/2\,.$$

$F_1 = 978MHz$, F_2 is the frequency of the cosite source, and n is an odd number giving the order of the IMP. The locations of some of the lower order IMPs are given in Table 2:

Table 2. Frequencies of Some Low Order Intermodulation Products

	IMP Order			
Cosite Frequency	3	5	7	9
1090 MHz	1202 MHz 866 MHz	1314 MHz 754 MHz	1426 MHz 642 MHz	1538 MHz 530 MHz
1030 MHz	1082 MHz 926 MHz	1134 MHz 874 MHz	1186 MHz 822 MHz	1238 MHz 770 MHz

An important issue is to determine the probability that one or another of these sets of IMPs occurs. This probability can be easily calculated from the information in Table 1 plus the facts that the duration (event interval) of a long ADS-B message is 403.2 μsec (= 420 bits x 0.96 μsec/bit) and there is one per second.

It can be shown that the average amount of time per second that IMPs caused by a particular cosite interferer are present is given by the formula:

$$T_{OV} = T_{UAT} T_{INT} N_{INT} .$$

$T_{UAT} = 403.2x10^{-6}$ sec, T_{INT} is the "event interval" from the table above, and N_{INT} is "events per second" from the table above. (This analysis assumes that *all* transmitters are always allowed to transmit, i.e., the bus is used only to control reception.) The results are shown in Table 3.

Table 3. Signal Overlap Statistics

Event Type	Overlap Time (seconds)
DME Interrogations	$5.36x10^{-7}$
ATCRBS Replies	$1.61x10^{-6}$
Mode S Interrogations	$1.16x10^{-7}$
Mode S Interrogations	$4.03x10^{-8}$
Whisper Shout Interrogations	$8.06x10^{-7}$

This means, for instance, that IMPs due to UAT-DME interference are present for 0.536 μsec out of each second. The worst case is due ATCRBS replies, which generate IMPs for an average of 1.61 μsec out of each second. The total effect is just the sum of the individual effects since the probability of multiple overlaps is extremely small. The total is

$$T_{OV}(total) = 3.07x10^{-6} \text{ sec} .$$

Another way to interpret this result is that it is equal to the product of the average duration of an IMP event and the probability of such an event in any given one second UAT interval. As a rough estimate, we can take the average length of an IMP event to be about 25 μsec, so the probability is about 0.1228. In other words, once every 8 seconds there may be a 25 μsec burst of IMP energy. This seems to be a very small effect, and it seems unlikely that this level of interference would not be tolerable. Also, the IMP probability calculated this way is an overestimate since these interference events are actually strings of pulses that are not actually transmitting with 100% duty factor. Thus, it seems that UAT transmitter blanking would not be necessary.

One could also ask the converse question, "What would the degradation to UAT be if transmitter blanking were implemented?" To analyze this, it will be assumed that the suppression bus acts in a "democratic" way, so that any transmission that has begun is allowed to continue until its end. No particular event type has special priority. In this case, we can assume that a UAT ADS-B message will not be sent whenever a cosite interference event begins prior to the UAT transmission and overlaps it. If so, it turns out that the blanking probability is just the fraction of time that the cosite interferers are transmitting. The contribution of a particular interferer is given by

$$P_{OV} = T_{INT} N_{INT} .$$

The individual contribution can be tabulated as follows:

Table 4. UAT Blanking Probabilities

Event Type	Blanking Probability (P_{OV})
DME Interrogations	0.00133
ATCRBS Replies	0.004
Mode S Interrogations	0.000288
Mode S Interrogations	0.0001
Whisper Shout Interrogations	0.002

The sum of all of these is 0.0077. Thus, allowing transmitter blanking would cause about 0.77% of all ADS-B messages to be omitted.

The bottom line is that if we permit UAT transmission, the fraction of time when there will be IMP interference present will be less than 3×10^{-6}. If transmission blanking is implemented, then the fraction of ADS-B transmissions omitted will be approximately 0.0077. Thus, the impact on UAT if transmission blanking is implemented will be greater than the impact of IMP generation if blanking is not implemented. (This conclusion is based on assumptions about the vulnerabilities of potential victim receivers that may need to be verified.)

It is tentatively suggested that transmission blanking *not* be implemented.